Designing Vocabulary Instruction in Mathematics

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Elementary school teachers have become aware in recent years of the critical role that vocabulary knowledge plays in the academic lives of their students. The report of the National Reading Panel (National Institute of Child Health and Human Development, 2000) intensified the spotlight by identifying vocabulary as a key component of effective reading instruction. This oft-cited report concluded that vocabulary instruction, when carefully tailored to the age and ability of the reader, leads to gains in reading comprehension. In response to this research, teachers have had to become experts on methods for promoting vocabulary development in the language arts. But does the facilitating effect of vocabulary knowledge extend beyond the domain of reading?

Language skills have become increasingly important in mathematics classrooms. The National Council of Teachers of Mathematics' (NCTM; 2000) *Principles and Standards for School Mathematics* now includes Communication as a process strand. Students need to be able to explain their problem-solving methods orally and in written form, both in the classroom and on high-stakes tests. Students are also expected to engage in conversations about mathematical ideas and through these conversations to "develop a language for expressing mathematical ideas and an appreciation of the need for precision in that language" (NCTM, 2000, p. 60). This focus on language is reflected in many state high-stakes math tests, which present students with complex word problems. Preliminary findings from research being conducted on the complexity of vocabulary within high-stakes tests indicate that students are expected to understand words that fall along a continuum from those that are used in many contexts to those that are very specific to mathematics (Pierce & Fontaine, 2008). The depth and breadth of a child's mathematical vocabulary is more likely than ever to influence a child's success in math. Yet few elementary school teachers bring effective vocabulary instruction into their math lessons.

What can elementary school teachers do to support their students in meeting the language demands of new mathematics curricula and high-stakes tests? First, teachers need to identify math vocabulary words. Next, they can apply research-based principles for vocabulary instruction in the mathematics classroom. To support elementary school teachers in these endeavors, we begin by reviewing best practices in vocabulary instruction. Next, we offer one way to analyze state high-stakes math tests to identify those words that children would benefit most from learning. Finally, we provide an example of how to apply robust vocabulary instruction in math.

Robust Vocabulary Instruction

In their hallmark book *Bringing Words to Life: Robust Vocabulary Development*, Beck, McKeown, and Kucan (2002) described research-based instructional strategies for promoting vocabulary development with children from the early grades through high school. A key finding in the book is that vocabulary instruction should be rich and lively so that students "develop an interest and awareness in words beyond vocabulary school assignments in order to adequately build their vocabulary repertoires" (p. 13). They made several recommendations for how to design what they call robust vocabulary instruction. First, Beck and colleagues advised that teachers should provide "student-friendly explanations" (p. 35) of the word rather than dictionary definitions. These explanations should explain the meaning of the word in everyday language, and they should characterize the word and how it is typically used. Second, teachers should engage the students in "rich and lively" (p. 13) activities that encourage deep processing of the word's meaning. These activities have been shown

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to raise students' vocabulary knowledge significantly (Beck & McKeown, 2007).

Vocabulary Demands on a High-Stakes Math Test

Which words present the greatest challenge for students facing high-stakes math tests? Research has shown that test questions that include unusual, *specific* math words or words with ambiguous meanings were more difficult for students to answer (Shaftel, Belton-Kocher, Glasnapp, & Poggio, 2006). Munroe and Panchyshyn (1995) referred to these two categories of mathematics vocabulary as *technical* and *subtechnical*, respectively. Technical words have a precise mathematical denotation that must be taught explicitly to students (e.g., *parallel*, *isosceles*). These words are often defined in math textbooks. Subtechnical words have a common meaning that students generally know already; however, they also have a less common, mathematical denotation that may be less familiar to students (e.g., *mean*, *table*). This ambiguity of meaning can be difficult for students.

As an example, Table 1 presents a list of the technical vocabulary words on the 2006 third-grade Massachusetts Comprehensive Assessment System (MCAS) math tests, released from the Massachusetts Department of Education. These words have a specific, mathematical denotation. Although teachers are aware of the need to teach the meaning of technical vocabulary words, the importance of teaching subtechnical vocabulary words may be less obvious. Although students may understand the common meaning of these words, vocabulary instruction is necessary to teach the meanings of for successful performance on this math test. A list of subtechnical vocabulary words included in the third-grade MCAS math test in 2006 is presented in Table 2.

To illustrate the ambiguous nature of subtechnical vocabulary words, consider the phrase *another way*, a fairly common phrase in the speech patterns of third-grade children. It is easy to imagine an 8-year-old saying to a friend, "There has got to be another way for us to get enough money for the video game." In everyday language, this phrase often implies that the current solution would work but is unattractive for some reason, sparking the quest for an alternative solution. Perhaps the children are disinclined to spend their Saturday cleaning out the attic to earn the money for the game, so they are seeking an easier method. In mathematics, however, the term *another way* has a somewhat different meaning. On item #2 of the test, third graders were presented with the following multiple-choice question: "Which of these is another way to write 6091?" (Massachusetts Department of Education, 2006, p. 204). The four options that students could choose from presented number sentences, only one of which equaled 6091. The correct solution (6000 + 90 + 1) is neither more attractive nor more efficient than the first way of representing the

Table 1
Technical Vocabulary Words on the Third-Grade MCAS Math Test

Words	Number of test items containing words
Number sentence	4
Rectangle	4
Add	2
Addition	2
Line plot	2
Bar graph	1
Centimeter	1
Data	1
Estimate	1
Fraction	1
Grid	1
Hundreds chart	1
Inch	1
Line of symmetry	1
Odd number	1
Ordered pair	1
Parallel	1
Perimeter	1
Pictograph	1
Quadrilateral	1
Square foot	1
Square unit	1
Subtract	1
Tally chart	1

Table 2
Subtechnical Vocabulary Words on the Third-Grade MCAS Math Test

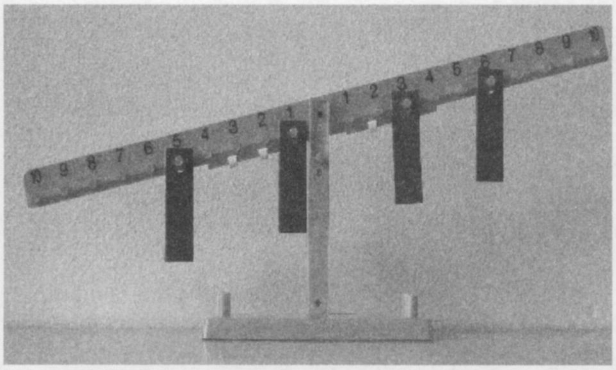
Words	Number of test items containing words	Definition in everyday language	Definition in mathematics problems
Key	5	An instrument by which the bolt of a lock is turned	Something that gives an explanation or identification or provides a solution
Pattern	3	Something designed or used as a model for making things	A sequence that repeats
Rule	3	A guide for conduct or action	A method for performing a mathematical action and obtaining a result
Another way	2	A different or distinct course of action	A way of equal value
Area	2	Open space, floor, or surface	Surface within a specific boundary
Shade	2	A place sheltered from the sun	To darken
True	2	Accurate, the opposite of false	A number sentence where the value to the left of the equal sign is the same as the value to the right
Belongs	1	To be the property of a person or thing	To be a part of a set or group
Foot/feet	1	The end part of the human body upon which an individual stands	A unit of measure based on the length of the human foot
Kind	1	Affectionate, loving, gentle	A type or variety of some category
Match	1	A contest, a tool for starting a fire	Two identical or similar items
Model	1	Something to be imitated, one employed to display clothes or other merchandise	Miniature representation
Order	1	To command to do something	Sequence in space, time, or quantity
Problem	1	Something difficult to deal with	Question or item in math
Result	1	A consequence or conclusion	Answer
Ruler	1	Someone who governs a country	Tool for measuring length
Table	1	A piece of furniture with four legs and a surface	Visual display of information

number. Rather, in this math problem, *another way* appears to mean equivalent, or of equal value.

Suggestions for Vocabulary Instruction in Mathematics

The principles of robust vocabulary instruction recommended for the language arts can be successfully applied to the domain of mathematics as well. Math vocabulary instruction should follow the recommendations of Isabel Beck and her colleagues by offering student-friendly definitions of math terms, encouraging deep processing of word meanings, providing extended opportunities to encounter words, and enriching the verbal environment of the mathematics classroom. This section describes an example of what vocabulary instruction might look like in the math classroom. It is offered to inspire the creativity of elementary school teachers to develop a set of vocabulary lessons that will complement their own math curricula. Additional resources on how to teach vocabulary in the content areas can be viewed at www.literacymatters.org/content/readandwrite/vocab.htm.

Figure 1
Number Balance Showing an Untrue Number Sequence



Note. Photograph by M.E. Pierce.

The first two principles of vocabulary instruction offered by Beck and colleagues (2002) recommend the development of student-friendly definitions and opportunities for deep processing of word meanings. According to Beck et al., these definitions should explain the meaning of the word in everyday language and characterize how the word is typically used. Students should also engage in activities that encourage deep processing of the word's meaning rather than simple repetition of the definition. These two principles of instruction are illustrated in the following fictional vignette, which shows how a teacher might help her students learn the subtechnical vocabulary word *true*.

Mrs. Lewis's Class Explores Truth in Mathematics

Mrs. Lewis was concerned that her third-grade students lacked deep appreciation of the meaning of the word *true*. The word *true* has a mathematical denotation that varies somewhat from its common meaning, and Mrs. Lewis decided it was important to make this point explicitly with her students. She started her lesson by asking the students to help her come up with a student-friendly definition of the word *true*. After some discussion, the class decided upon the following: *something that really happened or a fact, the opposite of false*. Mrs. Lewis reminded the class that most words have several meanings, depending on the situation in which the word is used. Then she introduced a second meaning of *true: a word used to describe a number sentence where the value on the left of the equal sign is the same as the value on the right of the equal sign*. Together, the class brainstormed examples of number sentences that were true (e.g., $4 + 3 = 7$, $5 \times 4 = 2 \times 10$) and number sentences that were not true (e.g., $1 + 2 = 5$; $3 \times 4 = 7$). The students then wrote the term, its everyday meaning, and its math definition in their math glossaries, while the teacher recorded it on their math word wall.

To provide her students with an opportunity for deep processing of this meaning of the word *true*, Mrs. Lewis engaged her students in a small group exercise using number balances. Together, the students in each group evaluated a series of number sentences to determine whether they were true or not true. True number sentences resulted in the number balance resting parallel to the ground, indicating that the value of the two sides was equal. Untrue number sentences resulted in the balance resting at an angle, indicating that one side of the number sentence had a higher (and thus a heavier) value. Figure 1 shows a number balance displaying an untrue number sentence: $3 \times 5 + 1 = 2 \times 6 + 3$. To represent $3 \times 5 + 1$, students placed 3 weights on peg 5 of the scale and 1 weight on peg 1 of the scale. To represent $2 \times 6 + 3$, students placed 2 weights on peg 6 of the scale and 1 weight on peg 3. The balance rested with the left arm lower than the right arm, indicating that the number sentence was untrue—the values on the two sides of the number sentence were not the same.

Bringing It All Together

Reading research has provided the field of education with invaluable insight to effective methods of teaching vocabulary, an endeavor of critical importance to our students' reading comprehension. However, the importance of vocabulary knowledge extends well beyond the domain of the language arts. In particular, proficiency in mathematics has increasingly hinged upon a child's ability to understand and use two kinds of math vocabulary words: math-specific words and ambiguous, multiple-meaning words with math denotations. Elementary school teachers can identify these words and design lessons that provide student-friendly definitions and offer opportunities for deep processing of word meanings. These efforts will help students to use the language of math.

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